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NEW DATA ON *DIPLACANTHUS KLEESMENTAE* VALIUKEVIČIUS, 1986 FROM THE VITEBSK REGIONAL STAGE (UPPER EMSIAN) OF THE LOWER DEVONIAN OF BELARUS

The paper presents new data on the acanthodian species *Diplacanthus kleesmentae*, whose isolated scales are often found in terrigenous and carbonate-terrigenous rocks of the Vitebsk Regional Stage of the Upper Emsian of the Lower Devonian of Belarus and are usually well preserved. A detailed study of the scales of this species made it possible to clarify its diagnosis, supplement the morphological and histological description of the scales, and clarify the features of their morphological variability, compare them with the scales of other known species of the genus *Diplacanthus*. In addition to the above-listed information, the paper also provides data on the facies restriction of scales of the acanthodians belonging to this species, their stratigraphic allocation and geographical distribution within the country. All currently known boreholes on the territory of Belarus, in which scales of this species were found, are mentioned. The rocks in which these scales were found are listed. The paper also presents the data of the associated organic remains (invertebrates, vertebrates and miospores) found together with the scales of this acanthodian representative. The correlation of the deposits of the Obol and Lepel Beds of the Vitebsk Regional Stage of the Upper Emsian of Belarus with the coeval sediments widespread in the adjacent territories of the Baltic States and Russia is given. The photographs of the external appearance of the scales and their thin sections are shown. The Stratigraphic Chart of the Devonian deposits of Belarus (2010) was used as the stratigraphic basis. The study of fossil ichthyofauna is of fundamental importance for the needs of practice — solving specific problems in prospecting, exploration, geological survey and other geological works.

Key words: acanthodians; *Diplacanthus kleesmentae*; Vitebsk Regional Stage; Upper Emsian; Lower Devonian; scales; Belarus.

Fig. 24. Ref.: 27 titles.

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НОВЫЕ ДАННЫЕ О *DIPLACANTHUS KLEESMENTAE* VALIUKEVIČIUS, 1986 ИЗ ОТЛОЖЕНИЙ ВИТЕБСКОГО ГОРИЗОНТА (ВЕРХНИЙ ЭМС) НИЖНЕГО ДЕВОНА БЕЛАРУСИ

В статье приводятся новые данные по акантодовому виду *Diplacanthus kleesmentae*, изолированные чешуи которого нередко встречаются в терригенных и карбонатно-терригенных породах витебского горизонта верхнего эмса нижнего девона Беларуси и обычно имеют хорошую сохранность. Детальное изучение чешуй этого вида позволило уточнить его диагноз, дополнить морфологическое и гистологическое описание чешуй, выяснить особенности их морфологической изменчивости, выполнить сравнение их с чешуями других известных видов рода *Diplacanthus*. Помимо перечисленных сведений в статье также приводятся данные о фациальной приуроченности чешуй этого вида акантодов, их стратиграфическом распределении и географическом распространении внутри страны. Указываются все известные к настоящему времени скважины на территории Беларуси, в которых были найдены чешуи этого вида. Перечисляются породы, в которых эти чешуи были найдены. Также в статье даются сведения по сопутствующим органическим остаткам (беспозвоночным, позвоночным и миоспорам), обнаруженным совместно с чешуями этого представителя акантодов. Приводится корреляция отложений обольских и лепельских слоев витебского горизонта верхнего эмса Беларуси с одновозрастными образованиями, широко развитыми на сопредельных территориях стран Балтии и России. Демонстрируются фотографии внешнего вида чешуй и их шлифов. В качестве стратиграфической основы использована Стратиграфическая схема девонских отложений Беларуси 2010 г. Изучение ископаемой ихтиофауны имеет принципиально важное значение для нужд практики — при решении конкретных задач в поисково-разведочных, геолого-съемочных и других геологических работах.

Ключевые слова: акантоды; *Diplacanthus kleesmentae*; витебский горизонт; верхний эмс; нижний девон; чешуи; Беларусь.

Рис. 21. Библиогр.: 27 назв.

Introduction. Separated scales of the acanthodian fish *Diplacanthus kleesmentae* are sometimes rather commonly found in the deposits of the Obol and Lepel Beds of the Vitebsk Regional Stage of the Lower Devonian on the territory of Belarus. Initially, scales of this species identified as *Diplacanthus* sp. were found in Estonia in the Rezēkne deposits of the Mehikoorma 421 borehole (depth range of 236.7 to 237.1 m) [1]. Then, in 1986, J. Valiukevičius [2] based on the study of such scales found them not only in Estonia, but also in Kaliningrad and Pskov regions of Russia, Lithuania, Latvia and Belarus erected and described the above-mentioned species. On the territory of the Baltic States and within the northwestern region of Russia, the scales of *Diplacanthus kleesmentae* are found both in the deposits of the Rezēkne Regional Stage of the Upper Emsian, as well as sometimes locally in the Pärnu sediments of the Lower Eifelian of the Middle Devonian [2—4]. In Kaliningrad region the separate scales of this species have been established in the rocks of the Rezēkne Regional Stage [3]. On the territory of Belarus, the isolated scales of this species are still reliably known only from deposits of the Vitebsk Regional Stage of the Upper Emsian of the Lower Devonian [2—10].

Materials and methods. The scales of the described species originate from terrigenous and carbonate-terrigenous rocks of the Obol and Lepel Beds of the Vitebsk Regional Stage, which are widely distributed on the territory of Belarus. The standard acid dissolution technique was used to extract them from these rocks. Formic 5 % and acetic 9—10 % acids were used. After dissolution of the rocks, the formed sediment was washed from clayey particles by multiple washing with water. Then the washed sediment was dried and viewed under a binocular stereoscopic microscope (MBS-1), after which the isolated scales were manually selected from it using thin brushes. The selected scales were studied both morphologically and histologically. The microstructure of scales was studied in thin sections or with use of anise oil. During their preparation, the scales on glass slides were placed in Canadian balsam softened when heated on an electric stove. Once the Canadian balsam was cured, the scales were ground down with the use fine abrasive powder. The photographs of thin sections of scales were taken with the help of a biological microscope BYLAN (TU RB 14724552.048-97) and an Axioskop 40 A Pol microscope, anise oil as an immersion liquid applied. The individual specimens of the best-preserved scales were also selected for photographing with a JSM-5610 LV scanning electron microscope (JEOL, Japan). The pictures were processed with the use of the Adobe Photoshop CS6 program, and the drawings were performed with the use of the program CorelDRAW 2019. The described scale samples are currently stored at the Belarusian National Technical University (BNTU) at the Mining Department in the palaeontological collection (Minsk).

Results and discussion. New data obtained from the study of the separate scales of *Diplacanthus kleesmentae* are given below.

Geological setting and stratigraphy. According to the literature [2—5] and the author's personal data [7—10] the scale findings of *Diplacanthus kleesmentae* in the territory of Belarus are reliably known from thirteen boreholes: Braslav 6, Braslav 14, Eividovichi 328, Kupcheli 325, Polotsk 1p, Chashniki 53, Liozno 1, Lyubuzh 1, Vilchitsy 1, Cherikov 1, Bykhov 1, Klimovichi 4п and Korma 1 (figure 1). The scales of this species in these boreholes were found in sandstones, siltstones, clays, marls and clayey dolomites belonging to the deposits of the Obol and Lepel Beds of the Vitebsk Regional Stage. Together with them occur numerous scales and fin spines of other species of acanthodians. In addition, various discrete skeletal elements of representatives of other groups of ichthyofauna (thelodonts, placoderms, chondrichthyans, sarcopterygians and actinopterygians) were found in these deposits. Of the invertebrates in the Obol and Lepel deposits, the individual valves of ostracods, valves of conchostracans and fragmentary and complete shells of inarticulate brachiopods were also found. Numerous findings of miospores are mainly known amongst the plant remains in these deposits [11].

1 — Braslav 6, 2 — Kupcheli 325, 3 — Eividovichi 328, 4 — Braslav 14, 5 — Polotsk 1p, 6 — Chashniki 53, 7 — Liozno 1, 8 — Lyubuzh 1, 9 — Vilchitsy 1, 10 — Cherikov 1, 11 — Bykhov 1, 12 — Klimovichi 4п, 13 — Korma 1

1 — Браслав 6, 2 — Купчели 325, 3 — Эйвидовичи 328, 4 — Браслав 14, 5 — Полоцк 1р, 6 — Чашники 53, 7 — Лиозно 1, 8 — Любуж 1, 9 — Вильчицы 1, 10 — Чериков 1, 11 — Быхов 1, 12 — Климовичи 4п, 13 — Кормянская 1

Figure 1. — Sketch map showing the borehole sections where the scales of *Diplacanthus kleesmentae* were found

Рисунок 1. — Карта расположения разрезов скважин, в которых были найдены чешуи *Diplacanthus kleesmentae*

According to the Stratigraphic chart of the Devonian deposits of Belarus in 2010 [11], the deposits of the Obol and Lepel Beds of the Vitebsk Regional Stage belong to the Upper Substage of the Emsian Stage of the Lower Devonian. These deposits correspond to the Rhabdosporites mirus—Gneudnaspora divellomedium Zone according to their contend miospores, and according to conodonts to the Polygnathus costatus patulus Zone, and correspond approximately to the lower part of the Laliacanthus singularis Zone in the acanthodian zonation [3; 5; 6; 11]. In the territory of the Baltic States, the age analogue of these deposits are the sediments of the Rezēkne Regional Stage [4; 12; 13], within the central part of Russia — the deposits of the Ryazhsk Regional Stage (Novobasovo Beds) [4; 14; 15], and in the territory of Spitsbergen, possibly, deposits of the lowermost of the Grey Hoek Formation [16].

Taxonomy

Class ACANTHODII Owen, 1846
Order Diplacanthiformes Berg, 1940
Family Diplacanthidae Woodward, 1891
Genus *Diplacanthus* Agassiz, 1844

Diagnosis. Dermal and endoskeletal pectoral girdle elements — pectoral and admedian spines, scapulocoracoid, procoracoid, pinnal and anterior ventral plates — articulate or are fused as a single structure on each side of body. The sides of the fin spines with multiple longitudinal ridges. Each eye is encircled by a single long plate plus multiple short plates. The scales are usually large, high, with a narrow, well-developed neck, and a flat or moderately convex base. The crown of the scales is flattened and ornamented with denticulated transverse ridges. The scales have a network of canals opening out via pores on the crown and high on the posterior neck. The fin spines are straightened or slightly curved, compressed laterally, with smooth longitudinal ridges, sometimes tuberculated proximally and with a double row of recurved denticles along the trailing edge [17; 18].

Type species. *Diplacanthus crassisimus* (Duff, 1842) [19] (*Diplocanthus crassisimus* Duff, 1842, by original designation).

Remarks. According to the results of the recent studies, for example, C. J. Burrow [18], the acanthodians belong to the stem group of the class of Chondrichthyes. In this paper, the acanthodians are still considered traditionally in a class rank, i.e., as an Acanthodii Owen Class, 1846 [20]. A detailed revision of the family Diplacanthidae Woodward, 1891 [21] of the order Diplacanthiformes Berg, 1940 [22] was made in paper [17].

Diplacanthus kleesmentae Valiukevičius, 1986 (Figures 2—21)

1975 *Diplacanthus* sp.; [1], p. 175; plate IV, figures 3*a* and 3*b*.

1985 *Diplacanthus* ? sp. nov. 1; [23], plate VI, figures 7*a* and 7*b*.

1986 *Diplacanthus kleesmentae* Valiukevičius, sp. nov.; [2], p. 113—114; plate I, figures 8 and 9; plate III, figure 8; plate IV, figure 6; text-figure 4, figures 4—6.

1995 *Diplacanthus kleesmentae*; [5], text-figures 2, 4 and 5.

1998 *Diplacanthus kleesmentae*; [3], p. 7 and 16; text-figures 8, 10, 12, 14 and 19.

2000 *Diplacanthus kleesmentae*; [4], text-figures 1 and 4.

2008 *Diplacanthus kleesmentae*; [6], p. 76 and 88; table 1.

2016 *Diplacanthus kleesmentae*; [7], p. 16, table.

2016 *Diplacanthus kleesmentae*; [17], p. 6 and 17.

2017a *Diplacanthus kleesmentae*; [8], p. 59.

2017b *Diplacanthus kleesmentae*; [9], p. 16 and 22; table; text-figure 3.

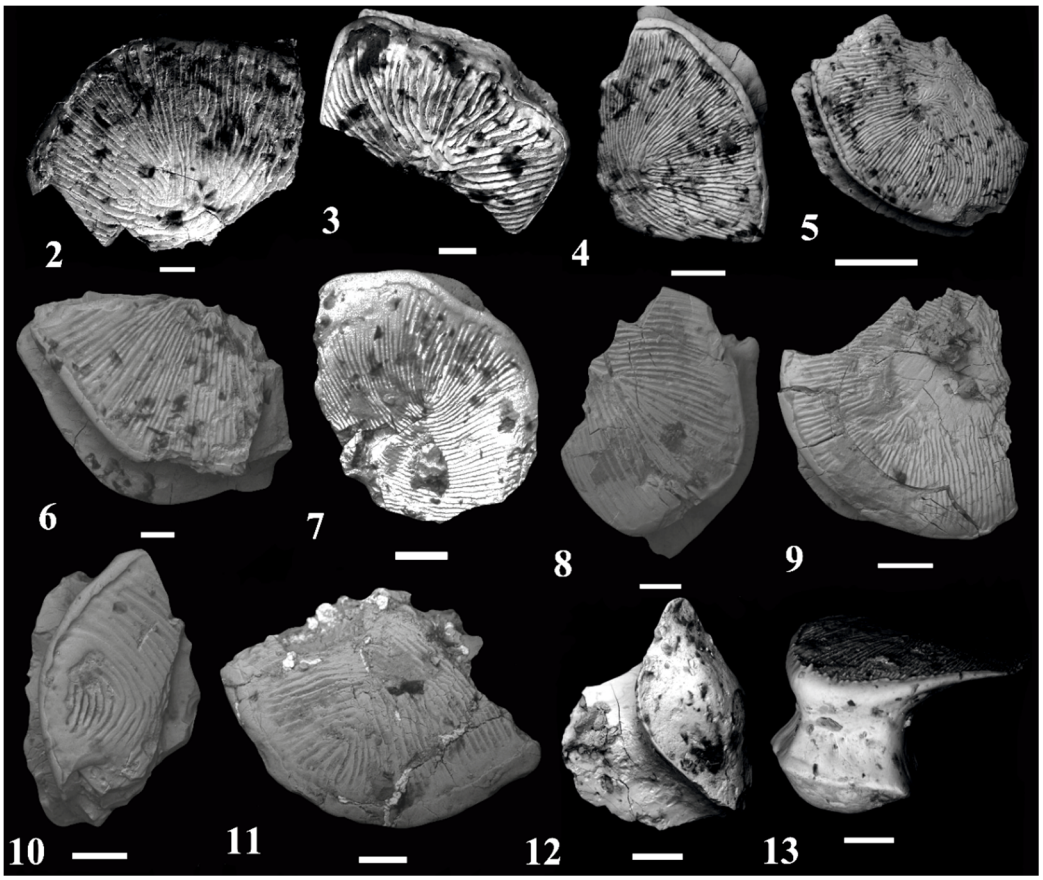
2021 *Diplacanthus kleesmentae*; [10], p. 44 and 47; text-figures 2, 3; plate III, figures 2—7.

2021 *Diplacanthus kleesmentae*; [18], p. 55.

Holotype. Institute of Geology, Center for Natural Sciences (Lithuania, Vilnius), № 45-1025 (plate IV, figure 6).

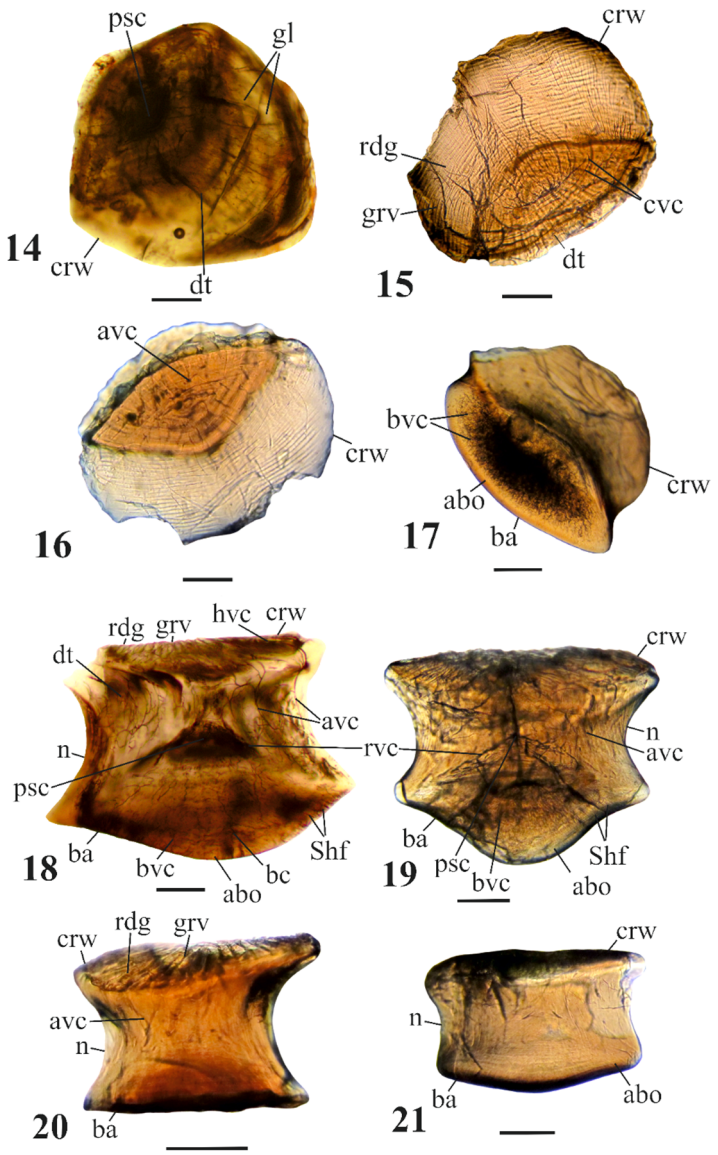
Type locality and horizon. Berzini 33 borehole, depth 409.8 m; Latvia; Lower Devonian, Upper Emsian, Rezēkne Regional Stage.

Material. Belarus, Vitebsk region, Beshenkovichi district, not far from the town of Beshenkovichi, Chashniki 53 borehole, depth range of 291.0 to 293.4 m, 2 scales; Belarus, Mogilev region, Mogilev district, near the village of Vilchitsy, Vilchitsy 1 borehole, depth 344.5 m, 3 scales; Bykhov 1 borehole, depths 321.5 and 324.2 m; near the village of Bolshaya Zimnitsa, Slavgorod district, Mogilev region, Belarus; 11 scales; Belarus, Mogilev region, Klimovichi district, near the town of Klimovichi, Klimovichi 4п borehole, depths 489.8 and 487.8 m, 29 scales; Belarus, Gomel region, Korma district, near the village of Barsuki, Korma 1 borehole, depth 340.2 m, 12 scales. All scale material was collected by D. P. Plax.



Figures 2—13 — Acanthodian scales of *Diplacanthus kleesmentae* from the Upper Emsian of the Lower Devonian of Belarus: 2 — Specimen No 116/51–1, Bykhov 1 borehole, depth of 321.5 m, × 100 scale, crown view; Vitebsk Regional Stage, Lepel Beds; **3** — Specimen No 116/53–1, Bykhov 1 borehole, depth of 324.2 m, × 140, scale, crown view; Vitebsk Regional Stage, Lepel Beds; **4** — Specimen No 121/44–6, Korma 1 borehole, depth of 340.2 m, × 85, scale, oblique crown view; Vitebsk Regional Stage, Lepel Beds; **5** — Specimen No 121/44 –3, Korma 1 borehole, depth of 340.2 m, × 50, scale, oblique crown view; Vitebsk Regional Stage, Lepel Beds; **6** — Specimen № 143/30–17, Klimovichi 4п borehole, depth of 487.8 m, × 100, scale, oblique crown view; Vitebsk Regional Stage, Obol Beds; **7** — Specimen No 143/30–18, Klimovichi 4п borehole, depth of 487.8 m, × 200, scale, oblique crown view; Vitebsk Regional Stage, Obol Beds; **8** — Specimen No 143/30–37, Klimovichi 4п borehole, depth of 487.8 m, × 120, scale fragment, oblique crown view; Vitebsk Regional Stage, Obol Beds; **9** — Specimen No 143/30–41, Klimovichi 4п borehole, depth of 487.8 m, × 90, scale, crown view; Vitebsk Regional Stage, Obol Beds; **10** — Specimen № 143/30–44, Klimovichi 4п borehole, depth of 487.8 m, × 150, scale fragment, oblique crown view; Vitebsk Regional Stage, Obol Beds; **11** — Specimen № 143/31–1, Klimovichi 4п borehole, depth of 489.8 m, × 130, scale fragment, crown view; Vitebsk Regional Stage, Obol Beds; **12** —Specimen № 121/44–1, Korma 1 borehole, depth of 340.2 m, × 75, scale, basal view; Vitebsk Regional Stage, Lepel Beds. **13** — Specimen № 121/44–5, Korma 1 borehole, depth of 340.2 m, × 70, scale, lateral view; Vitebsk Regional Stage, Lepel Beds. Scale bar 100 μm (**2, 3, 6, 8, 10, 11**); 200 μm (**4, 7, 9, 12, 13**); 500 μm (**5**)

Рисунки 2—13 — Чешуи *Diplacanthus kleesmentae* из отложений верхнего эмса нижнего девона Беларуси: 2 — Экземпляр № 116/51–1, скважина Быхов 1, глубина 321,5 м, × 100, чешуя, вид сверху; витебский горизонт, лепельские слои; **3** — Экземпляр № 116/53–1, скважина Быхов 1, глубина 324,2 м, × 140, чешуя, вид сверху; витебский горизонт, лепельские слои; **4** — Экземпляр № 121/44–6, скважина Кормянская 1, глубина 340,2 м, × 85, чешуя, вид с наклоном сверху; витебский горизонт, лепельские слои; **5** — Экземпляр № 121/44–3, скважина Кормянская 1, глубина 340,2 м, × 50, чешуя, вид с наклоном сверху; витебский горизонт, лепельские слои; **6** — Экземпляр № 143/30–17, скважина Климовичи 4п, глубина 487,8 м, × 100, чешуя, вид с наклоном сверху; витебский горизонт, обольские слои; **7** — Экземпляр № 143/30–18, скважина Климовичи 4п, глубина 487,8 м, × 200, чешуя, вид с наклоном сверху; витебский горизонт, обольские слои; **8** — Экземпляр № 143/30–37, скважина Климовичи 4п, глубина 487,8 м, × 120, фрагмент чешуи, вид с наклоном сверху; витебский горизонт, обольские слои; **9** — Экземпляр № 143/30–41, скважина Климовичи 4п, глубина 487,8 м, × 90, чешуя, вид сверху; витебский горизонт, обольские слои; **10** — Экземпляр № 143/30–44, скважина Климовичи 4п, глубина 487,8 м, × 150, фрагмент чешуи, вид с наклоном сверху; витебский горизонт, обольские слои; **11** — Экземпляр № 143/31–1, скважина Климовичи 4п, глубина 489,8 м, × 130, фрагмент чешуи, вид сверху; витебский горизонт, обольские слои; **12** — Экземпляр № 121/44–1, скважина Кормянская 1, глубина 340,2 м, × 75, чешуя, вид снизу; витебский горизонт, лепельские слои; **13** — Экземпляр № 121/44–5, скважина Кормянская 1, глубина 340,2 м, × 70, чешуя, вид сбоку; витебский горизонт, лепельские слои. Масштабная линейка: 100 μm (**2, 3, 6, 8, 10,11**); 200 μm (**4, 7, 9, 12,13**); 500 μm (**5**).



abo — acellular bone,
avc — ascending vascular canal,
bvc — base vascular canals,
ba — base,
cvc — circular vascular canal,
crw — crown,
dt — dentine tubule,
psc — primordial scale,
gl — growth lamella,
grv — groove,
hvc — horizontal vascular canal,
n — neck,
rdg — ridge,
rvc — radial vascular canal,
Shf — Sharpey's fibres

abo — бесклеточная костная ткань,
avc — восходящий сосудистый канал,
bvc — сосудистые каналы основания,
ba — основание,
cvc — циркулярный сосудистый канал,
crw — крона,
dt — дентиновый каналец,
psc — примордиальная чешуя,
gl — пластина нарастания,
grv — борозда,
hvc — горизонтальный сосудистый канал,
n — шейка,
rdg — гребешок,
rvc — радиальный сосудистый канал,
Shf — Шарпеевы волокна

Figures 14—21 — Microstructure of the scales of *Diplacanthus kleesmentae*: 14 — horizontal section of the scale crown. Specimen No 121/44–19, Korma 1 borehole, depth 340.2 m, Vitebsk Regional Stage, Lepel Beds; **15** — horizontal section of the scale crown. Specimen No 121/44–25, Korma 1 borehole, depth 340.2 m, Vitebsk Regional Stage, Lepel Beds; **16** — scale horizontal view in anise oil. Specimen No 143/30–46, Klimovichi 4п borehole, depth 487.8 m, Vitebsk Regional Stage, Obol Beds. **17** — horizontal view of the base in anise oil. Specimen No 143/30–48, Klimovichi 4п borehole, depth 487.8 m, Vitebsk Regional Stage, Obol Beds; **18** — scale vertical longitudinal section. Specimen No 121/44–20, Korma 1 borehole, depth 340.2 m, Vitebsk Regional Stage, Lepel Beds; **19** — scale vertical longitudinal view in anise oil. Specimen No 143/30–47, Klimovichi 4п borehole, depth 487.8 m, Vitebsk Regional Stage, Obol Beds; **20** — scale lateral view in anise oil. Specimen No 121/44–27, Korma 1 borehole, depth 340.2 m, Vitebsk Regional Stage, Lepel Beds; **21** — scale lateral view in anise oil. Specimen No 143/30–46, Klimovichi 4п borehole, depth 487.8 m, Vitebsk Regional Stage, Obol Beds. Scale bar of 200 μm (**14—21**)

Рисунки 14—21 — Микроструктура чешуй *Diplacanthus kleesmentae*: 14 — горизонтальный срез чешуи через крону. Экземпляр № 121/44–19, скважина Кормянская 1, глубина 340,2 м, витебский горизонт, лепельские слои; **15** — горизонтальный срез чешуи через крону. Экземпляр № 121/44–25, скважина Кормянская 1, глубина 340,2 м, витебский горизонт, лепельские слои; **16** — горизонтальный вид чешуи в анисовом масле. Экземпляр № 143/30–46, скважина Климовичи 4п, глубина 487,8 м, витебский горизонт, обольские слои; **17** — вид основания в анисовом масле. Экземпляр № 143/30–48, скважина Климовичи 4п, глубина 487,8 м, витебский горизонт, обольские слои; **18** — вертикальный продольный срез чешуи. Экземпляр № 121/44–20, скважина Кормянская 1, глубина 340,2 м, витебский горизонт, лепельские слои; **19** — вертикальный продольный вид чешуи в анисовом масле. Экземпляр № 143/30–47, скважина Климовичи 4п, глубина 487,8 м, витебский горизонт, обольские слои; **20** — вид чешуи сбоку в анисовом масле. Экземпляр № 121/44–27, скважина Кормянская 1, глубина 340,2 м, витебский горизонт, лепельские слои; **21** — вид чешуи сбоку в анисовом масле. Экземпляр № 143/30–46, скважина Климовичи 4п, глубина 487,8 м, витебский горизонт, обольские слои. Масштабная линейка 200 μm (**14—21**)

Published records. Belarus, Vitebsk region, Braslav district, near the town of Braslav, Braslav 6 borehole, depth range of 315.0 to 328.0 m; Belarus, Vitebsk region, Sharkovshchina district, near the village of Germanovichi, Braslav 14 borehole, depth range of 235.0 to 240.0 m; Belarus, Vitebsk region, Braslav district, near the village of Kupcheli, Kupcheli 325 borehole, depth 275.9 m; Belarus, Vitebsk region, Braslav district, near the village of Eividovichi, Eividovichi 328 borehole, depth range of 254.4 to 259.0 m; Belarus, Polotsk district, Vitebsk region, northwest of the town of Polotsk, Polotsk 1p borehole, depth range of 305.0 to 308.0 m; Belarus, Vitebsk region, Liozno district, near the village of Liozno, Liozno 1 borehole, depth range of 510.5 to 516.5 m; Belarus, Mogilev region, Mogilev district, near the village of Lyubuzh, Lyubuzh 1 borehole, depth range of 356.1 to 365.2 m; Belarus, Mogilev region, Cherikov district, near the town of Cherikov, Cherikov 1 borehole, depth range of 411.8 to 429.2 m. About 30 scales [2].

Diagnosis. The scales are usually large, up to 1.8 mm long. The crown of the scales is often thin, with rounded anterior margins; it can be round, oval, elongated-oval, rounded-rectangular, rounded-rhomboid and regular-rhomboid. On the crown there is a sculpture like a “fingerprint” formed by numerous ridges and grooves. In the anterior section of the crown some ridges can branch in two, less often into three. Along the anterior margin of the crown there is a distinct narrow ridge-like unsculptured border. The neck of the scales is high, thin, well developed. The base is moderately convex, rhomboid, rounded-rhomboid, elongated-oval, often with a slightly expressed apex located in the middle. There are up to nine growth lamellae in the crown and neck. The growth lamellae are superpositional. The ascending vascular canals in the neck are sinuous and branched, with many processes. The radial vascular canals are very complex, large, multi-branched, penetrating the entire neck area. The circular vascular canals are distinct, well-expressed, and form arcuate branches. The longitudinal horizontal vascular canals in the crown are bush-like – the mouths of several large branches converge. The acellular bone tissue of the base, in addition to the banded-situated Sharpey’s fibers contains sinuous and branched vascular canals rising up from its outer surface.

Description. *Morphology*. The scales are usually large, 0.6 to 1.8 mm long and 0.5 to 1.2 mm wide. The height of the scales is usually 0.7—0.9 mm. The crown of the scales is usually thin. Its anterior margin is rounded, in some scales it is slightly tilted forward, the lateral angles are slightly rounded, and the posterolateral margins converge smoothly, without usually forming a sharp posterior angle. The shape of the crown of the scales can be round, oval, elongated-oval, rounded-rectangular, rounded-rhomboid with a slightly elongated posterior section and regular-rhomboid shape. The sculpture on the crown is represented by numerous ridges and grooves forming a peculiar pattern resembling a “fingerprint” pattern. The thin linear grooves and low ridges between them in the anterior medial section of the crown converge symmetrically with opposite sides, and in the posterior section they are located in a semicircle parallel to the margin of the crown. Sometimes on the crown – one or two grooves are wider and deeper. In the anterior section of the crown some ridges can branch in two, less often in three parts. In the medial section of the crown a gently sloping longitudinal concavity or depression is not rare observed. A distinct narrow ridge-like unsculptured border runs along the anterior margin of the crown. The neck of the scales is usually high, thin, well developed, only in rare specimens is it relatively low and weakly expressed. There are sometimes narrow vertical furrows on its posterolateral walls. The rim outlining the junction of the neck and base is clear, uneven and well developed. The base is moderately convex or slightly flattened, in cross section it is diamond-shaped, rounded-rhomboid, elongated-oval, but does not extend beyond the anterior margin of the crown. The apex of the base is usually weakly expressed and located in the middle, but may be absent.

Histology. The crown of the scales is composed of mesodentine and is penetrated by numerous complicated radial, ascending, circular and longitudinal horizontal vascular canals. They are well-expressed, large, multi-branched, and intertwined with a dense network of processes of radial vascular canals that are located above the surface of the base and penetrate the entire region

of the neck of the scales. Here they are intertwined with sinuous, branched ascending vascular canals and rarely form lacuna-like extensions. The confinement of ascending vascular canals to individual growth lamellae is indistinct. The durodentine is represented by thin strips only in the central parts of the latest growth lamellae of the crown. The circular and longitudinal horizontal vascular canals penetrate even the latest growth lamellae. The circular vascular canals are distinct, rather wide and form arcuate branches. The longitudinal horizontal vascular canals, as a rule, consist of several large, bush-like situated branches and in the anterior part of the crown rush towards the center of the scale, and in the posterior section of the crown they stretch towards the posterior extremity of the crown. The vast majority part of the thin, narrow, sinuous dentine tubules that intertwine with them are oriented in a similar way. The base of the scales is dense and growth lamellae are clearly observed on them it. It is composed of acellular bone tissue, which in addition to the clearly defined, narrow, relatively long, striped-situated Sharpey's fibers also contains wider, sinuous and branched vascular canals directed centripetally towards the primordial scale. These vascular canals are noticeably inferior in size to the crown canals.

Variability. The scales of this species vary in crown shape, neck height, base configuration and degree of its convexity. The sculpture of the crown varies in the number of ridges, the presence of branched ones among them at the anterior margin of the crown. On the crown, a sculpture resembling a kind of "fingerprint" may have some individual features in the details of this pattern.

Comparison. From the scales of *Diplacanthus pecherensis* Valiukevičius, 2003a [24] the scales of *Diplacanthus kleesmentae* differ in the much larger size of the scales, as well as slightly in the shape of the base and configuration of the crown of the scales. In addition, they differ strongly in the sculpture on the crown of the scales. Despite the fact that the internal structure of the scales of *Diplacanthus pecherensis* is poorly understood, it can still be noted that the scales of this species have up to six growth lamellae in the crown, consisting of specific mesodentine with well-developed ascending and radial vascular canals located high in the neck area. The upward directed bushy networked dentine tubules are located separately in the growth lamellae without any connections, and the primordial scale contains a complicated knot of interwoven vascular canals, part of which are widened. Morphologically the scales of *Diplacanthus kleesmentae* differ from those of *Diplacanthus poltnigi* Valiukevičius, 2003b [25] in the size of the scales and in a peculiar sculpture of the crown like a "fingerprint". In histological relation, the scales of *Diplacanthus poltnigi* differ from the scales of *Diplacanthus kleesmentae* in the nature of the structure of the sinuous ascending vascular canals in the neck and their smaller branches containing lacunae, as well as the multibranched radial vascular canals above the base. The scales of *Diplacanthus kleesmentae* differ from those of *Diplacanthus tenuistriatus* Traquair, 1894 [17; 26] in size, and differ significantly in crown sculpture and base shape. There are some differences in the internal structure of the scales. In the scales of *Diplacanthus kleesmentae* the radial and ascending vascular canals in the neck are much better expressed, and the longitudinal horizontal vascular canals in the crown are thinner, but more branched. The lacuna-like extensions of the dentine tubules contained in the neck are much more common in the scales of *Diplacanthus tenuistriatus*. The scales of *Diplacanthus kleesmentae* have thinner and more numerous crown growth lamellae — up to nine, while the scales of *Diplacanthus tenuistriatus* have no more than eight crown growth lamellae. The scales of *Diplacanthus kleesmentae* differ from those of *Diplacanthus solidus* Valiukevičius, 2003b [25] in having much larger scales, the shape and sculpture of the crown of the scales, a larger number of growth lamellae in the crown and neck, a different structure of the radial and ascending vascular canals in the neck, and a special character of the mesodentine. The scales of *Diplacanthus kleesmentae* differ from the scales of *Diplacanthus gravis* Valiukevičius, 1988 [27] in having larger scales, and in possessing higher height of the neck of the scales, and in the sculpture on the crown of the scales. In the internal structure the differences between these compared species are more distinct. The scales of *Diplacanthus kleesmentae* have up to nine

growth lamellae, a differing character of the location and structure of the radial vascular canals in the neck, and no mesodentine with numerous processes directed upwards from the horizontal and circular vascular canals are found in the crown. *Diplacanthus kleesmentae* resembles *Diplacanthus crassisimus* (Duff, 1842) [17; 19] in the character of the arrangement of sculptural elements on the crown; however, the ridges of the latter protrude in relief; moreover, each of them seems to consist of individual tubercles closely adjacent to each other neighbor and placed in a semicircle.

Facies. The scales are found mainly in clayey, clastic and clayey-carbonate rocks, which are predominantly formations of a shallow, desalinated marine basin.

Geological age and geographical distribution. Lower Devonian, Emsian, Upper Substage, Rezēkne Regional Stage of the Baltic States, Kaliningrad region and northwestern region of Russia; Obol and Lepel Beds of the Vitebsk Regional Stage of Belarus. Middle Devonian, Eifelian, Lower Substage, Pärnu Regional Stage of the Baltic States and northwestern region of Russia.

Belarus occurrences. Vitebsk region, Braslav 6 borehole (depth range of 315.0 to 328.0 m), Braslav 14 borehole (depth range of 235.0 to 240.0 m), Kupcheli 325 borehole (depth 275.9 m), Eividovichi 328 borehole (depth range of 254.4 to 259.0 m), Polotsk 1p borehole (depth range of 305.0 to 308.0 m), Chashniki 53 borehole (depth range of 291.0 to 293.4 m), Liozno 1 borehole (depth range of 510.5 to 516.5 m); Mogilev region, Lyubuzh 1 borehole (depth range of 356.1 to 365.2 m), Vilchitsy 1 borehole (depth 344.5 m), Cherikov 1 borehole (depth range of 411.8 to 429.2 m), Bykhov 1 borehole (depths 321.5 and 324.2 m), Klimovichi 4п borehole (depths 489.8 and 487.8 m); and Gomel region, Korma 1 borehole (depth 340.2 m).

Conclusions. The study of the collected scale material of the species *Diplacanthus kleesmentae* originating from the deposits of the Vitebsk Regional Stage of Belarus allowed the author to significantly supplement and clarify the description of the scales of this species in morphological and histological aspects. This study clarifies the limits of their morphological variability, establishes their facies confinement, and elucidates their stratigraphic distribution and, due to the new findings, indicates a wide geographical distribution within the Vitebsk Regional Stage in Belarus.

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